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MEASUREMENT OF INDUSTRIAL SEWING NEEDLE TEMPERATURE WITH DIFFERENT EXPERIMENTAL TECHNIQUES

ANKUSH SHARMA[1 & 2] & VINAY MIDHA[2]

[1]*Department of Textile Engineering, Jawahar Lal Nehru Govt. Engineering College, Sundernagar (Himachal Pradesh), India*

[2]*Department of Textile Technology, Dr. B.R. Ambedkar National Institute of Technology, Jalandhar (Punjab), India*

ABSTRACT

This article is about measuring sewing needle temperatures with three different methods (thermal camera, pyrometer, and implanted thermocouple) on an industrial lockstitch machine. The needle temperature test was performed for a cumulative period of 60 seconds at varying system speeds from 1500 rpm to 4500 rpm. The results of the experimental techniques are compared at various speeds of sewing. This article will be functional in respect of verification with experimental results for investigators who use theoretical models in sewing needle temperature measurement. Results represent when using thread, needle temperature is still higher than when no thread is used that contradicts the findings of some investigators who consider the thread as a heat sinker.

KEYWORDS: Needle Temperature, Thermal Camera, Thermocouple, Pyrometer & Sewing Thread

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Original Article

1. INTRODUCTION

The sewing method is one that is mostly used in many business sectors. Industrial sewing machines sew “stitches” for products in every field, from conventional apparel products, bags, shoes, and sportswear, to car seat covers. It is well known that the effectiveness of sewing machines, particularly when using synthetic sewing threads and/or fabrics consisting of synthetic fibres, is limited not by other mechanical factors but by the needle heat produced during the process. The needle-heating issues are typical to many other sectors in addition to the fashion industry. Examples include tufting carpets, punching needles, stitching stitches, binding procedures on clothing and leather, etc.

In heavy industrial sewing, high needle temperature during sewing is a key problem. This needle heating results limited sewing speed, and hence loss of production rate. High needle temperature also causes sewing thread strength loss, which can lead to needle eye fatigue, causing thread breakage, cloth breakage, scorching, puckering (wrinkle by sewing). At the same, it may cause weakened and tempered needles. [1]

Higher sewing speeds were used to increase the production rate. In high speed industrial sewing machines, the typical sewing speed used is between 2000 rpm to 6000 rpm. The repeated insertion of the needle through the fabric at a higher rate during stitching creates contact between the needle and the fabric to create heat that is absorbed by the needle and the fabric. The heat that the needle consumes accumulates, while the heat that is absorbed by the cloth extends out around the surface. [2]

Based upon sewing parameters and conditions needle temperature raises up to 350$^{\circ C}$. This high temperature weakens the sewing thread because sewing thread tensile strength is temperature dependent.

Researchers claim that there could be about 30-40% strength loss due to this high temperature [3]. There are basically two methods for experimental measurement of needle temperature, contact method and contact less method. In the contact method, there is the use of temperature sensitive materials (waxes, paints or colours) or thermocouples. Whereas in contact less methods infrared techniques are used which comprises the use of pyrometers and thermal cameras. Since needle movement is extremely high, it is very difficult to measure precise temperature [4]. Some researchers also suggest theoretical models for the prediction of needle temperature. Which are based upon analytical modelling (sliding contact method or lumped variable method) and finite element analysis (FEA) [5].

This work uses thermal camera, pyrometer, and implanted thermocouple to estimate the sewing needle temperature of a lockstitch machine at various process speeds and times. There is also a comparative assessment of results obtained from all methods for prediction of method which gives the highest accuracy and the most repeatable performance. This research will also be beneficial for verification of theoretical models by comparing experimentally measured needle temperature with estimations of theoretical models.

2. MATERIAL AND METHODS

In this paper, three different methods (thermal camera, pyrometer, and implanted thermocouple) were used to test the needle temperature at high speed industrial sewing. The conditions for all experiments are kept constant at $27^{\circ C} \pm 2^{\circ C}$ and 65% ± 2% RH.

The instruments used for the experiments are Lockstitch Sewing Machine (Brother S7200C), Omega -K type thermocouple (5SC-TT-(K)-36-(36)), thermocouple detector / end device (Omega -MWTC-D-K-868), Thermal Camera (Optris PI 1M), Pyrometer (Optris CT laser 3M). The sewing machine needle used is Schmetz 130/705 H-J CF, Nm 100/16 which is coated with chrome finish. Properties of denim fabric and sewing thread used are discussed in Table 1.

The GSMs of fabrics are calculated with GSM cutter and electronic weighing balance. The fabric thickness is measured with the thickness tester (Karl Schröder KG) at a constant compressive load of 2 KPa. Commercially available polyester/polyester core spun sewing thread of linear density (40 X 2 tex) is used. This sewing thread is used in the experimental work as compared to cotton sewing threads because of their least reversible strain. The twist per unit length is measured using a direct counting method in accordance with ASTM-D1423.

Consequently, because lockstitches are used to stitch denim pants within the assembly, denim pants were chosen for analysis within leg assembly seams. The fabric is sewn four folded and stitch length was kept constant i.e. 12 stitch/inch with maximum sewing time of 60 seconds. Process of sewing was completed without stopping along this time. That procedure has been checked 20 times each and standard deviations are reported on the findings. At the same time, sewing cycle was performed with and without thread to decide the position of sewing thread in the difference in temperature.

Table 1: Denim Fabric and Sewing Thread Properties

Denim Fabric Properties		Sewing Thread Properties	
Fabric Type:	100% Cotton Denim	Thread Type:	Polyester/polyester core spun
Weight GSM:	379.1	Yarn linear Density:	40 x 2 (tex)
EPI X PPI:	95 X 52	TPI:	16
Thickness:	1.73 mm	Twist Direction:	Z/S (ply / single)
Weave:	3/1 Twill	Coefficient of friction:	0.24

2.1 Thermal Camera Method

Thermal camera system is a type of Infrared thermography (IRT), a science used to obtain and process thermal information from non-contact measuring devices [6]. IRT is based on infrared (under red), a type of electromagnetic radiation with wavelengths longer than those of visible light. Thermal camera collects infrared radiation emitted by sewing needle and converts it into an image-forming electrical signal. Pictures obtained from thermal cameras are transformed into visible images by adding a colour to each level of infrared radiation. The effect is an image of a false hue, called a thermogram. The measurement of temperature from infrared photographs, however, is not only dependent on measured radiation; it also depends on the configuration of the internal camera and on the emissiveness of the radiating energy source. To obtain accurate measurements a calibration system is necessary.

Emissivity means how much radiation at the same temperature from the target object is released as opposed to that from a black body. Low-emissivity materials emit less infrared radiation at the same temperature than materials of high emissivity. Accurate calculation of emissivity is of special significance in materials with low emissivity. However, temperature calculation is especially difficult in items with low emissivity, such as polished sewing needle, because minor differences in emissivity result in large changes in the resulting temperatures.

Since the sewing needle is very thin and polished, measuring the right emissivity is extremely difficult. However, some investigators found emissivity of the chrome finished needle about 0.06 – 0.08 [7]. In this study, emissivity of sewing needle was measured to be 0.075 at 39ºC according to ASTM E1933-99a [8]. Sewing needle was covered with vinyl electrical tape of known emissivity 0.96 for measuring the needle temperatures. Optris PI 1M is a continuous filming thermal camera, which is used for sewing needle temperature measurement. Experiments were conducted with or without sewing thread at speeds between 1500 – 4500 rpm. Figure 1 shows thermal image of sewing needle without thread and with thread at 3500 rpm after 10 seconds of sewing. With the advent of high-speed camera with higher frame rate up to 1kHz, it is possible to measure needle eye temperature at higher sewing speeds but the difference in emissivity of the sewing thread (around 0.9) and sewing needle (0.075) makes it difficult to measure [9].

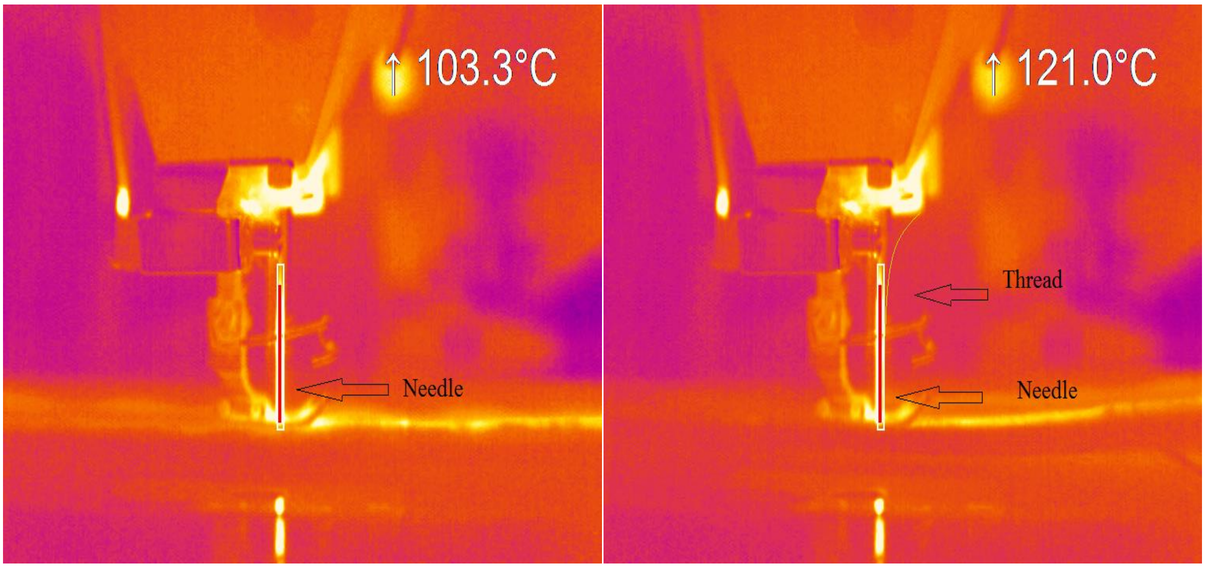

Figure 1: Needle Eye Temperature with or without Sewing Thread Measured by Thermal Camera.

2.2 Pyrometer

Pyrometer is the most basic type of Infrared thermography (IRT). Temperature analysis of IRT-based needle application is concentrated primarily on the experimental system. The most appropriate configuration is job based and the precision of the tests is heavily affected. IRT is also in real time, allowing for fast-moving targets and rapidly changing thermal patterns to be acquired. The IRT procedure is non-invasive. This thus in no way interferes with or affects the goal.

In needle temperature calculation, where emissivity is not necessarily understood because it varies during the process of stitching. In the case of a thermal camera, the emissivity measurement is done using a high-performance radiometer. Multiple factors are considered, such as the effect of temperature and wavelength, and the effect of roughness. This research indicates that an erroneous calculation of emissivity is causing major temperature changes dependent on these variables. Hence, an alternative approach is used for calculating emissivity. Multi-wavelength pyrometer-based technique is used to solve this problem. This methodology assumes, however, that a clear relationship exists between wavelength and emissivity [6]. Three wavelengths are taken in case of needle emissivity, and the needle emissivity is approximated by constant, power, and exponential functions. This approach is especially useful for metal surface measurements, as the approximation function for their spectral emissivity is a power function and this approach finds limited measurement error. Sewing needle distance to optical pyrometer is 70 mm. Optris CT laser 3 M has short wave length ranges of 2.3 μm to minimize reading error for readings on surfaces of uncertain emissivity but the pyrometer cannot be used at speeds greater than this because the needle moves more than 3500 times per minute, rendering it difficult to aim the pyrometer on the needle. Experiments were done with and without thread stitching. Figure 2 displays the experimental pyrometer set-up for heat needle probing.

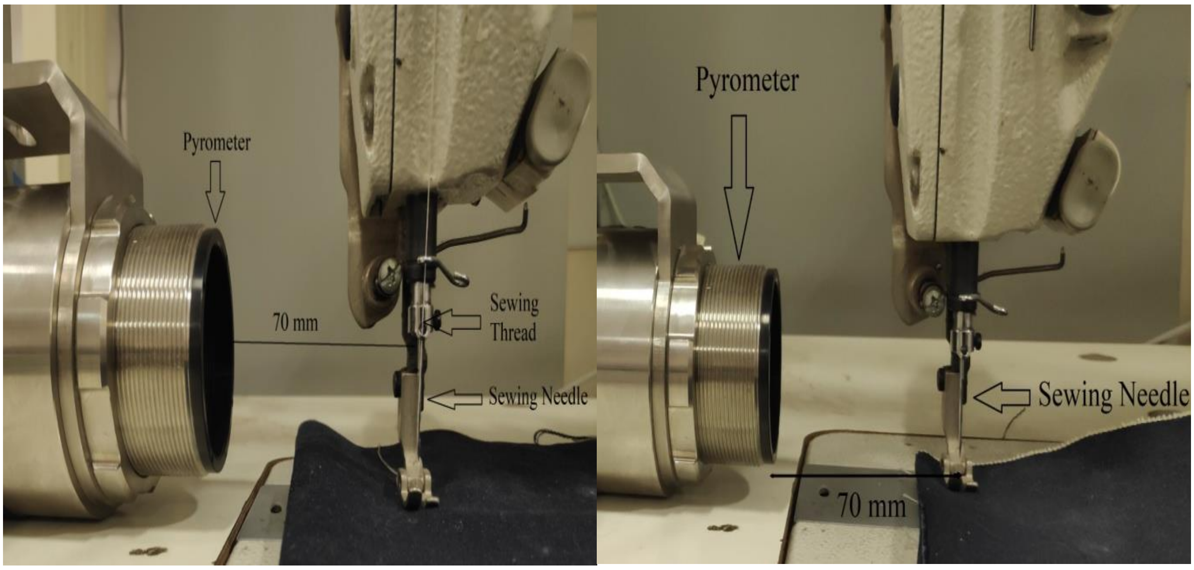

Figure 2: Experimental Setup of Pyrometer for Needle Heat Measurement with and without Sewing Thread.

2.3 Implanted Thermocouple Method

Implanted thermocouple for measuring the temperature of a sewing needle consists of a K type micro thermocouple (5SC-TT-(K)-36-(36)), which is attached to part of the length along the sewing needle. K type micro thermocouple is soldered to the walls of the longitudinal groove formed in the sewing needle. Measuring end of the thermocouple is located within 5 mm by needle hole where the highest temperature is reached while sewing, because here, there is a relative

movement of the sewing thread with respect to sewing needle which is attached to the sewing mechanism.

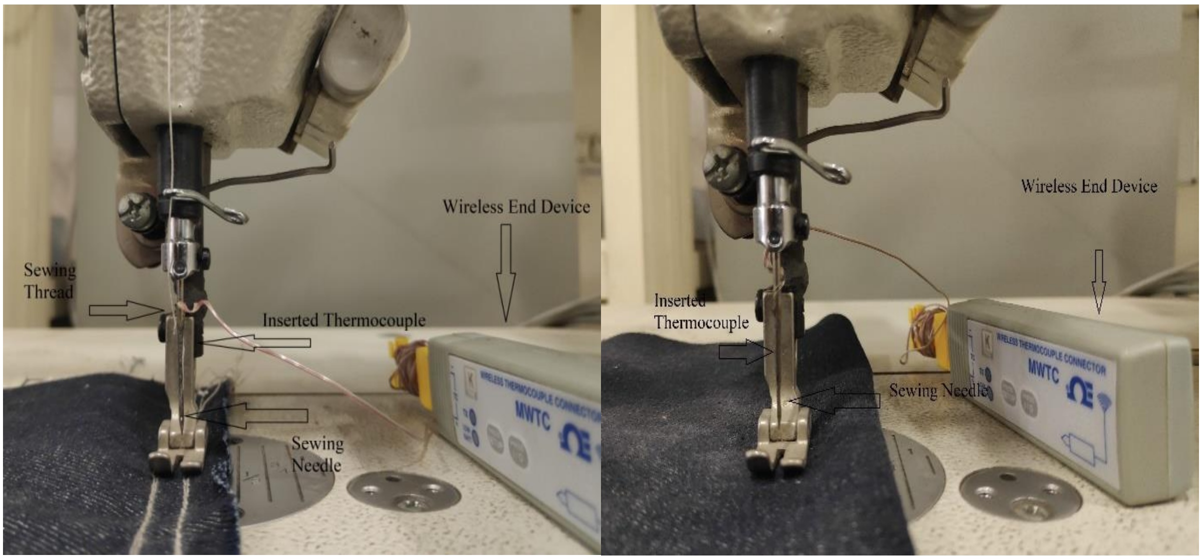

Figure 3: Implanted Thermocouple Method for Needle Heat Measurement with and without Thread.

The temperature was calculated at various sewing speeds and this process proved to be successful because it produced constant temperature results every 2 seconds. Thermocouple remained inside the needle groove during sewing and measurements were recorded wirelessly on the computer using a wireless end tool (Omega-MWTC-D-K-868). Figure 3 demonstrates thermocouple positioning with and without thread in embedded thermocouple process for the needle heat calculation. Experiments were performed with or without sewing thread and it was found that this approach proved highly effective and had lower standard deviation compared with other measuring methods.

3. RESULT AND DISCUSSIONS

It was difficult to calculate the needle temperature with the pyrometer at machine speeds above 3500 rpm; thus, the thermal camera and the implanted thermocouple system were used to test the needle temperature at sewing speeds of 4500 rpm (with and without thread). It has been found that each of three experimental methods reveal substantial variations in needle temperature with and without thread. So, the function of sewing thread leading to needle temperature is especially important. It is observed that the needle temperature rises sharply up to first 20 s of sewing and thereafter, increases marginally.

The mean (without thread) temperature for the various experimental measuring methods at a system speed from 1500 rpm to 4500 rpm are shown in table 2. Results obtained indicate that after 60 seconds of stitching, the implanted thermocouple system, and the pyrometer display about the same mean needle temperature. While thermal camera often provides nearby results, in the case of thermal camera measurements the standard deviation is much higher. After 60 seconds of stitching at machine speed of 4500 rpm, implanted thermocouple method reveals the maximum needle (without thread) temperature, i.e. 204 ˚C with low standard deviation of 2.8 followed by a thermal camera measurement process of 197 ˚C with high standard deviation of 8.4.

Table 2: Needle Heat Measurement without Sewing Thread						
S. No.	**Applied Method for Measurement**	**Time (Sec.)**	**Temperature (˚C) at Different RPMs**			
			1500 RPM(S.D.)	**2500 RPM(S.D.)**	**3500 RPM(S.D.)**	**4500 RPM(S.D.)**
1.	Thermal Camera	0	27 (0.9)	28 (0.8)	26 (0.7)	28 (1.1)
2.	Thermal Camera	10	73 (5.3)	89 (5.9)	103 (5.4)	123 (7.5)
3.	Thermal Camera	20	87 (4.9)	109 (8.1)	151 (6.3)	183 (5.9)
4.	Thermal Camera	30	91 (5.8)	108 (7.6)	150 (8.2)	176 (5.4)
5.	Thermal Camera	40	95 (6.1)	118 (7.2)	157 (7.5)	169 (6.7)
6.	Thermal Camera	50	97 (5.4)	116 (8.0)	152 (7.9)	199 (8.7)
7.	Thermal Camera	60	101 (4.8)	123 (6.8)	153 (6.2)	197 (8.4)
8.	Pyrometer	0	29 (0.6)	27 (0.6)	27 (0.7)	26 (0.6)
9.	Pyrometer	10	72 (3.9)	98 (5.1)	105 (3.6)	--
10.	Pyrometer	20	101 (3.7)	113 (5.4)	148 (4.5)	--
11.	Pyrometer	30	100 (4.1)	129 (3.9)	158 (4.8)	--
12.	Pyrometer	40	102 (4.5)	126 (3.7)	154 (3.8)	--
13.	Pyrometer	50	107 (4.8)	128 (4.3)	152 (5.2)	--
14.	Pyrometer	60	105 (5.2)	125 (4.6)	160 (3.9)	--
15.	Implanted Thermocouple	0	27 (0.4)	27 (0.4)	27 (0.5)	28 (0.3)
16.	Implanted Thermocouple	10	92 (1.8)	99 (2.5)	105 (2.9)	128 (3.1)
17.	Implanted Thermocouple	20	103 (2.3)	105 (3.2)	114 (3.3)	178 (2.9)
18.	Implanted Thermocouple	30	106 (1.7)	113 (2.8)	125 (4.1)	195 (2.4)
19.	Implanted Thermocouple	40	111 (2.5)	128 (1.8)	136 (3.7)	196 (1.9)
20.	Implanted Thermocouple	50	112 (3.2)	125 (2.3)	155 (2.9)	199 (2.4)
21.	Implanted Thermocouple	60	112 (2.7)	127 (2.5)	159 (3.4)	204 (2.8)

Table 3 displays the mean temperature relation of the needle (with thread) for the various experimental measurement methods at a machine speed from 1500 rpm and 4500 rpm. It was found that implanted thermocouple after 60 seconds of stitching with the lowest standard deviation 2.1 shows the highest mean needle temperature 237 ˚C at 4500 rpm machine speed, while thermal camera and pyrometer show high standard deviation performance. Since measurement of IRT needle temperature is strongly dependent on the emissivity of needle radiating energy and for low-emissivity items such as polished sewing needle, minor emissivity differences result in large differences in the resulting temperatures.

Table 3: Needle Temperature Measurement with Sewing Thread

S. No.	**Applied Method for Measurement**	**Time (Sec.)**	**Temperature (˚C) at Different RPMs**			
			1500 RPM(S.D.)	**2500 RPM(S.D.)**	**3500 RPM(S.D.)**	**4500 RPM(S.D.)**
1.	Thermal Camera	0	29 (1.0)	27 (1.1)	28 (0.8)	26 (0.9)
2.	Thermal Camera	10	85 (8.4)	102 (9.9)	121 (8.7)	135 (9.5)
3.	Thermal Camera	20	122 (8.3)	149 (9.3)	173 (9.6)	199 (9.3)
4.	Thermal Camera	30	136 (10.2)	169 (9.6)	196 (8.9)	215 (8.7)
5.	Thermal Camera	40	139 (9.3)	177 (8.6)	189 (10.4)	219 (11.2)
6.	Thermal Camera	50	137 (7.9)	182 (10.2)	195 (9.9)	207 (10.5)
7.	Thermal Camera	60	143 (8.7)	174 (8.9)	197 (10.7)	221 (9.8)
8.	Pyrometer	0	25 (0.7)	25 (0.7)	26 (0.7)	26 (0.6)
9.	Pyrometer	10	87 (4.1)	109 (3.9)	123 (3.5)	--
10.	Pyrometer	20	128 (3.6)	156 (4.7)	173 (4.7)	--
11.	Pyrometer	30	131 (4.4)	168 (3.8)	180 (5.4)	--
12.	Pyrometer	40	135 (3.9)	169 (5.3)	184 (4.5)	--
13.	Pyrometer	50	138 (3.7)	171 (5.1)	187 (4.9)	--
14.	Pyrometer	60	139 (4.2)	172 (4.9)	194 (5.1)	--
15.	Implanted Thermocouple	0	27 (0.3)	27 (0.4)	27 (0.2)	28 (0.4)
16.	Implanted Thermocouple	10	83 (2.1)	110 (2.0)	134 (2.3)	151 (1.9)

Table 3: Contd,..						
17.	Implanted Thermocouple	20	135 (1.8)	159 (2.5)	171 (2.7)	203 (2.5)
18.	Implanted Thermocouple	30	144 (2.5)	167 (2.9)	185 (2.1)	219 (2.2)
19.	Implanted Thermocouple	40	144 (2.2)	172 (2.3)	189 (3.1)	226 (2.8)
20.	Implanted Thermocouple	50	149 (1.9)	175 (3.2)	191 (2.7)	232 (2.4)
21.	Implanted Thermocouple	60	151 (2.3)	178 (2.7)	193 (1.9)	237 (2.1)

The analysis reveals that the needle temperature in both without the sewing thread and with the sewing thread increases dramatically against machine speed and time. In comparison, the needle with sewing thread induces a higher rate of needle temperature rise in response to increased machine speed and sewing time. Figures 4 and 5 show rise in needle (with and without thread) temperature against increase in machine speed from 1500 rpm to 4500 rpm and time of sewing from 10 to 60 seconds using implanted thermocouple method and thermal camera method, respectively. Figure 6 shows rise in needle (with and without thread) temperature against increase in machine speed from 1500 rpm to 3500 rpm and time of sewing from 10 to 60 seconds using pyrometer method.

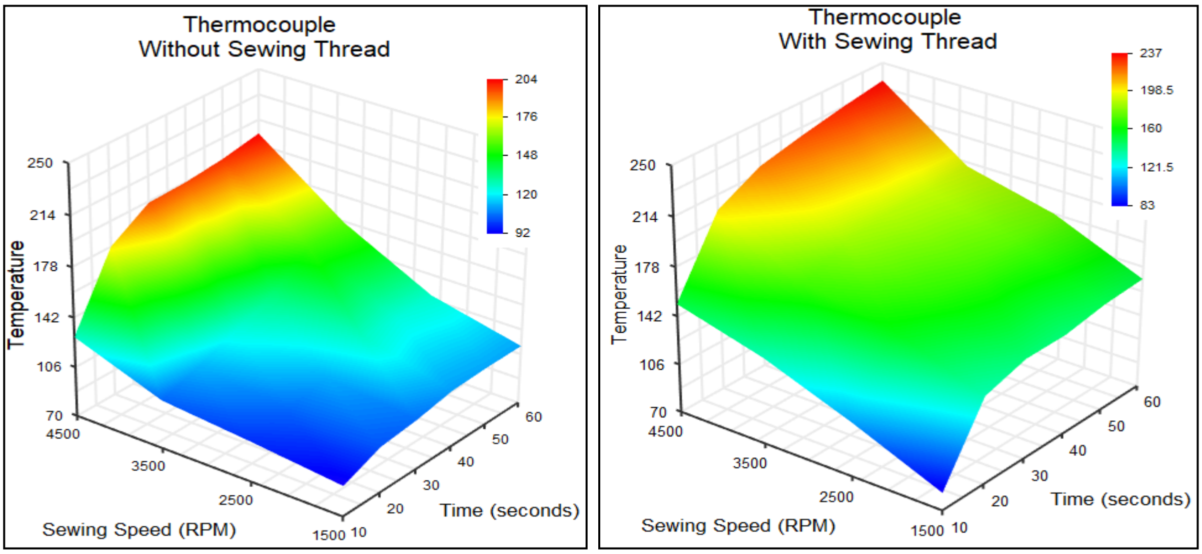

Figure 4: Sewing Machine RPM and Sewing Time at Needle Temperature (with and without Sewing Thread) using Thermocouple Heat Measurement Process.

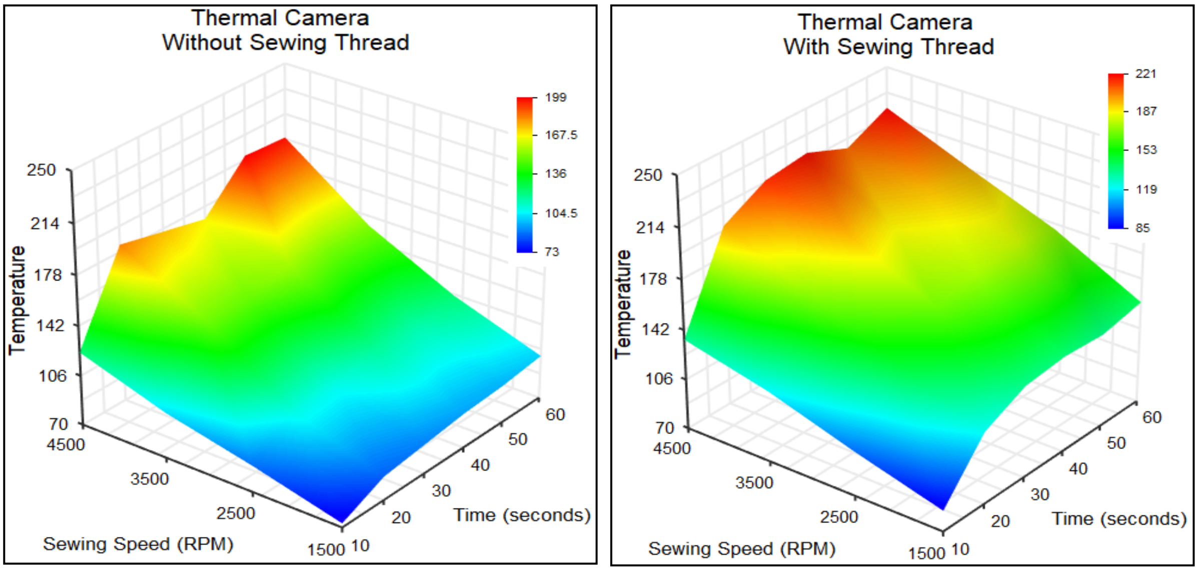

Figure 5: Sewing Machine RPM and Sewing time at Needle Temperature (with and without Sewing Thread) using Thermal Camera Heat Measurement Process.

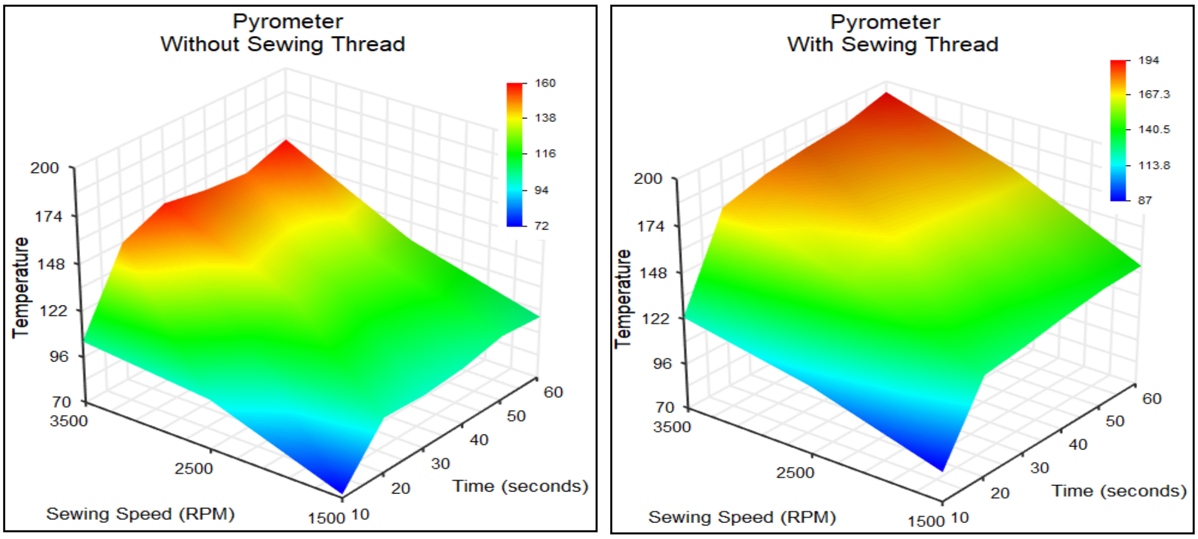

Figure 6: Sewing Machine RPM and Sewing Time at Needle Temperature (with and without Sewing Thread) using Pyrometer Heat Measurement Process.

4. CONCLUSIONS

There is always higher needle temperature when thread is used during needle heat measurement. It is due to the friction between the thread and the needle and at higher machine speeds, this difference is much greater. For longer stitching time, the needle temperature increases, but the raise rate becomes slower after 20 seconds of stitching, because after this point the needle heating mechanism is balanced with the temperature of the surrounding atmosphere. The implanted thermocouple system can be used to calculate the correct sewing needle temperature; with the use of a wireless end unit; sewing needle temperature can be determined at all machine speeds in any 2 seconds with minimal standard deviation in performance. This makes implanted thermocouple method especial over IRT (thermal camera and pyrometer); where the emissivity of the needle and other energy sources transmitted from the surface of the needle induces significant variation in the resulting needle temperature.

REFERENCES

1. *Mazari, A., & Havelka, A. (2013). Influence of Needle Heat during Sewing Process on Tensile Properties of Sewing Thread. Tekstilec, 56(4).*
2. *Qinwen, L. & Liasi, E. (2001). A study on the needle heating in heavy industrial sewing- part I International Journal of Clothing Science and Technology, 13(5), 351-367.*
3. *Midha, V. K., Mukhopadhyay, A., Chattopadhyay, R., & Kothari, V. K. (2009). Studies on the changes in tensile properties of sewing thread at different sewing stages. Textile Research Journal, 79(13), 1155-1167.*
4. *Qinwen, L. & Liasi, E. (2001). A study on the needle heating in heavy industrial sewing- part II International Journal of Clothing Science and Technology, 13(2), 87-105.*
5. *Li, Q., Liasi, E., Zou, H. J., & Du, R. (2001). A study on the needle heating in heavy industrial sewing-Part 1: analytical models. International Journal of Clothing Science and Technology.*
6. *Maldague, X. (2001). Theory and practice of infrared technology for non-destructive testing.*
7. *Mazari, A., Havelka, A., & Lubos, H. E. S. (2014). Experimental techniques for measuring sewing needle temperature. Tekstil ve konfeksiyon, 24(1), 111-118.*
8. *ASTM E1933-99a, (1999). Standard Test Methods for Measuring and Compensating for Emissivity Using Infrared Imaging Radiometers. ASTM International, West Conshohocken, PA.*
9. *Mazari, A., & Havelka, A. (2013). Tensile properties of sewing thread and sewing needle temperature at different speed of sewing machine. In Advanced Materials Research (Vol. 627, pp. 456-460). Trans Tech Publications Ltd.*
10. *Seif, A. M. "Investigating the seam slippage of satin fabrics." International Journal of Textile and Fashion Technology 4.5 :1-10.*
11. *Mona M. Nasr& Manal A. Seif, "Influence of Embroidery Stitches on the Properties of Textile Fabrics", International Journal of Textile and Fashion Technology (IJTFT),Vol. 6, Issue 6,pp, 1-8.*
12. *Manal A. Seif & Shaimaa M. Ahmed, "Impact of Printing Techniques on the Properties Behaviour of Seamed Textile Fabrics", International Journal of General Engineering and Technology (IJGET),Vol. 7, Issue 2, pp; 1 – 1.*
13. *Manal A. Seif & Mona M. Nasr, "A Comparative Study of Assembling Methods of Nonwoven Bags Traditional Sewing vs Welding Seaming", International Journal of General Engineering and Technology (IJGET), Vol. 5, Issue 6, pp; 7-22*